PROJECT: STARHAWK

Instruction Manual

Physics 11

By Mr. Stephenson
Revised by Mr. Klaassen

Sir Winston Churchill Secondary School
7055 Heather Street
Vancouver, B.C.
V6P 3P7

Introduction:

Your mission, should you choose to accept it, is to assemble a team to complete the following tasks:

- Ensure a safe environment for the experiment
- produce a force vs. time graph of a model rocket engine
- use a variety of methods to predict the maximum altitude to which your rocket will fly
- construct and launch a model rocket
- measure the rocket's maximum altitude
- compare the measured value to your predicted values and suggest reasons for any differences

Your team should have people responsible for each of the tasks listed above.

Materials:

Individual Team:
2 A6-4 model rocket engines
Recovery wadding
2 Clinometers
1 set igniters
1 GPS device or measuring tape
USB Memory stick
Pasco Capstone software download at home – see download and installation instructions
1 Starhawk model rocket kit and white glue or a completed rocket model

Provided on Launch Day:
The launch pad
1 rocket bracket
1 Pasco Force Sensor
1 USB Link
1 C clamp
1 flathead screwdriver
1 netbook computer or other data collection device (e.g. GLX)

Procedures:

Part 1: Optional Rocket Construction-complete at home

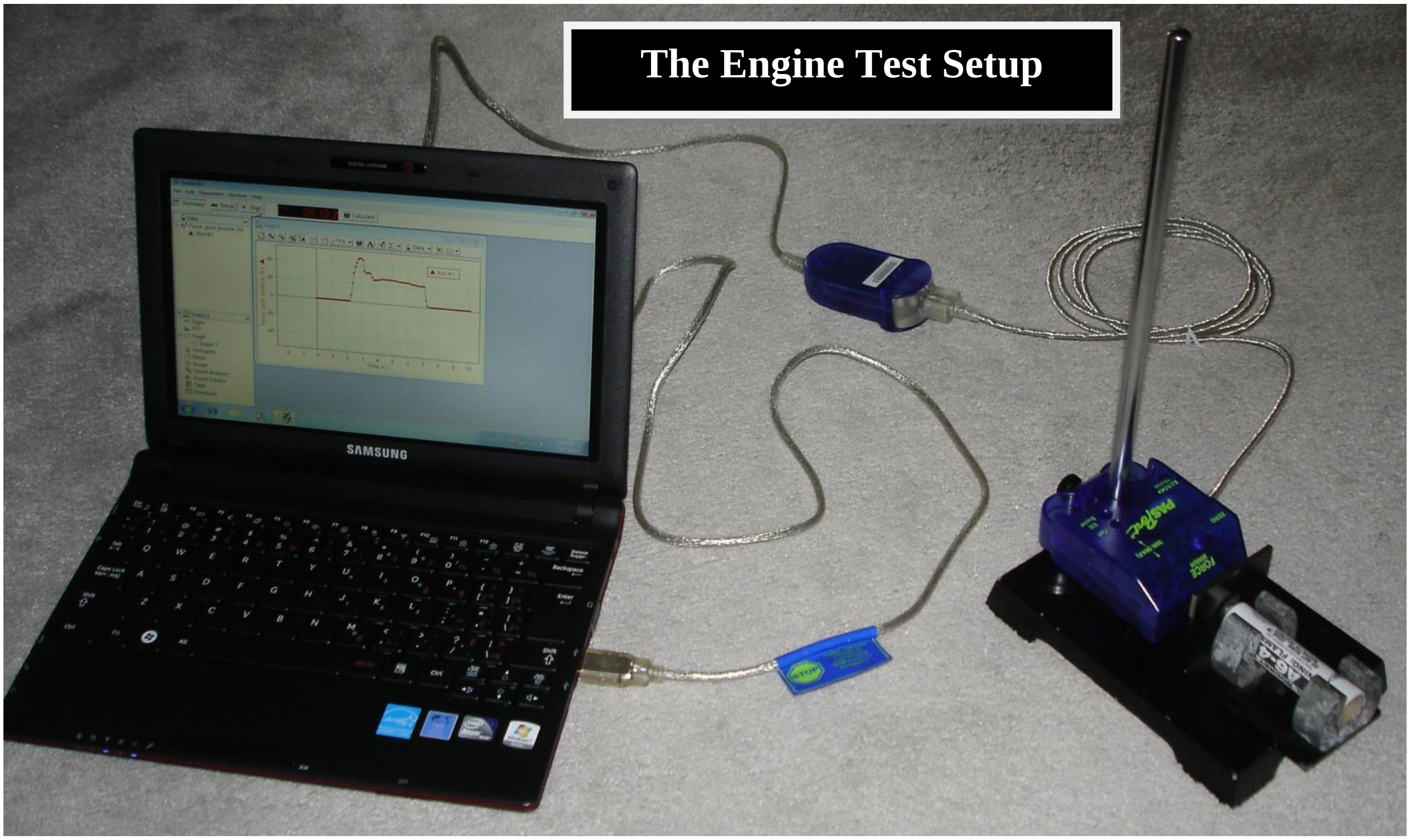
1. Follow the instructions provided for constructing your rocket. You may personalize it using paints, markers, stickers, etc. Give your rocket sufficient time to dry before launching. Do not add extra weights or anything that could deflect the path.

Part 2: Initial measurements in the superlab

1. Get individual team materials listed above.
2. Prepare your rocket for launch – make sure that recovery wadding has been inserted to protect the recovery system (streamer or parachute) and the engine is inserted. ***Do not*** insert the igniters at this time.
3. Be sure to measure the mass of your rocket ***prior*** to launch. You will subtract the mass of burned fuel to get the mass of your rocket ***after*** launch. (See data booklet).
4. Measure the mass of the individual rocket engine before the test. (one engine is for the rocket, one engine is for the engine test)

Part 3: The Engine Test – to be conducted outdoors

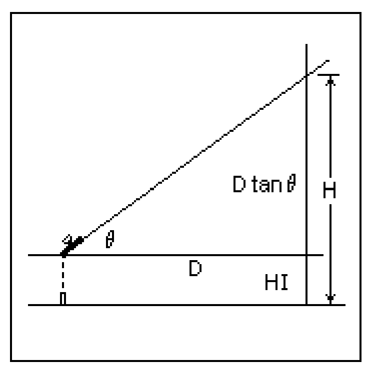
1. Check that the rocket bracket is secured into the force sensor – use a flathead screw driver to tighten.
2. Check that the force sensor is secured onto the stand and firmly in place.
3. Secure the stand using the C clamp to a large solid object such as the edge of a picnic table or bring a chair+umbrella if it is raining to conduct the experiment under cover.
4. Attach the USB link and then plug the USB link into your data collection device. Start the Capstone software and drag the graph icon on the right to the screen. Click on y axis label and set to "force".
5. Place a model rocket engine into the rocket bracket – make sure the ***large open end*** of the engine (not the nozzle end) touches the vertical plate of the engine bracket
6. Install the engine igniters following the procedures outlined for pre-launch.
7. Connect the launch controller and move back a safe distance. Make sure the area behind the nozzle end of the engine is clear.
8. Push the "start" button so you are collecting data.
9. Insert the key into the launch controller – give a loud short countdown and press the launch button. ***Note:** If your engine ***does not fire*** – remove the key from the launch controller and wait at least one minute before approaching the test area.
10. Do not approach the rocket until it has finished burning (including the recovery charge). Be aware that some of the materials may be hot for a short time after firing. Press the "stop" button to end your data collection. Make sure you save your raw data before you start making changes to it. Save a second copy to your usb.
11. Record the mass of the rocket engine after the test and calculate the mass of fuel burned. (see data booklet).



See the **Data Booklet** to complete your data analysis. ***Please note:** each member of your team must complete a **Data Booklet**.

Part 3: Launch and Altitude Measurements

1. Prepare the launching pad and rocket. Insert the igniters into the rocket engine (see "Launch Procedures")
2. Before connecting the launch controller, have two people in your team start from the launch pad and, using either a GPS device or a measuring tape, move as far away over level ground as possible. Make note of the horizontal distance (D) from the launch site. You will also need to know the distance from the ground to the clinometers (HI). The launch controller can be connected while these people move into place.



3. Indicate to the person looking after launch control that you are ready. The launch controller should then insert the key into the launch controller and **give a countdown** – pressing the firing button at "lift-off".
4. Watch the rocket launch and afterwards, record any important qualitative observations in your data booklet - when the rocket has reached its highest altitude, view the rocket along the top of the clinometer. Both observers should measure and record the angle (θ).
5. Use the data you collected to calculate the altitude (H) reached by your rocket. Take the average of the two results.

Part 4: Modifying the Raw Data and Making Calculations – complete at home

We will be using the results of your engine test to help predict the maximum possible altitude of your rocket. ***We will ignore air resistance in our calculations.*** Before you proceed you will need to modify the graph of the raw data you collected from your rocket test.

1. When looking at your graph of force and time, click on select data (yellow pen with blue dots) and select the portion of the data where the engine is firing. **You should ignore the ejection charge portion of your graph.
2. Adjust the scale of the x and y axes of your graph so that the data you need fills as much of the graph as possible. Do this by moving the pointer over the axis values – it should change into a wavy line with two arrows on either end. Left click and scroll to either increase or decrease the scale. Do the same for the other axis.
3. Click on the Σ symbol in the toolbar above your graph to get the average force. Click on the area under the curve button (the one beside the Σ) A box should appear on your graph with the area under the F-t graph, the impulse.
4. Print out a copy of your modified graph and attach it to the data pages you will hand in. ** Before you shut down the Capstone program, I recommend saving a copy. Save your work by selecting "Save Activity As…" under the File heading. Choose a name for your raw file and click the "save" button and save on the usb as well.
5. Use your graph and the instructions below to complete the calculations in the Data Booklet.

Method 1 – Using Newton's Laws

1. Calculate the acceleration during the burn using Newton's Second Law. Remember to use the net force which is the ***average thrust*** 'F_{avg}' – the ***average weight*** '$\mathbf{m_{avg}g}$'.

   $$a = (F_{avg} - m_{avg}g)/m_{avg}$$

2. Use the acceleration and the burn time to calculate the final velocity 'v_f' of the rocket and the distance 'd_1' it travels during the burn time.

   $$v_f = at \qquad \text{and} \quad d_1 = ½\, at^2$$

3. Find the additional distance to reach zero vertical velocity as the rocket continues to coast upward:

   $$d_2 = v_f^2/2g$$

4. Calculate the total theoretical altitude: $d_1 + d_2$.

Method 2 – using the Law of Conservation of Momentum

1. Calculate the total impulse or change in momentum of the rocket: $F\Delta t$ (impulse) = $m\Delta v$ (change in momentum). Be aware that there are ***two*** forces providing impulse during the time the engine is firing – the ***thrust*** and ***gravity***, so the change in momentum $\mathbf{\Delta p}$ of the

rocket will be given by the ***area*** under the force vs. time graph – the average force of gravity x t where t is the time for the burn (as taken from your force vs. time graph).

$$\text{area under f vs. t graph} - m_{avg}gt = \Delta p = m_{final}\Delta v$$

2. Calculate the final upwards velocity of the rocket after the burn has completed:

$$v_f = \Delta p/m_{final}$$

3. Use the the velocity from step 2 (method 2 above) to calculate the distance traveled during the burn time **t**:

$d_1 = ½ (v_f)t$ - since $v_i = 0$ assuming uniform acceleration

4. Find the additional distance to reach zero vertical velocity as the rocket continues to coast upward:

$$d_2 = v_f^2/2g$$

5. Calculate the total theoretical altitude: $d_1 + d_2$.

Data Studio Software Download and Installation Instructions:

With our school site license you can download and use Pasco Capstone software at home or at school. Download at:
https://www.pasco.com/downloads/capstone/pasco-capstone-trial/index.cfm
With site license key: 18tmi-qg1n1-0p1v0-ohid9-g0ome-c891l
Or just use the 30day free trial.

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LAUNCH PROCEDURES

ROCKET MOTORS with Igniters INSTRUCTIONS and SAFETY INFORMATION

IMPORTANT: DESIGNED FOR AGES 10 TO ADULT. ADULT SUPERVISION IS RECOMMENDED FOR THOSE UNDER 12 YEARS OF AGE WHEN FLYING MODEL ROCKETS. READ AND FOLLOW ALL INSTRUCTIONS, LAUNCH PROCEDURES AND THE N.A.R. SAFETY CODE DURING ALL YOUR MODEL ROCKET ACTIVITIES.

WARNING - FLAMMABLE:
READ INSTRUCTIONS BEFORE USE.
1.4 S Model Rocket Motor (NA 0323)/ Articles Pyrotechnic (UN 0432). Contains flammable solid propellant model rocket motors. Damaged, defective, or unwanted motors should be destroyed by soaking in water. Do not burn or expose to excessive heat. Keep out of reach of small children. Ignite only by electrical means.

CAUTION - Always use caution around launch pad and launch rod tip to avoid eye injury.

STORAGE: Keep motors in a cool dry place where temperatures will never rise above 150 degrees Fahrenheit.

IN CASE OF FIRE: Use water or fire extinguisher foam to prevent ignition of rocket motors.

FIRST AID: For minor burns use first aid burn ointment. For severe burns consult a physician. In case propellant is swallowed, induce vomiting and call a physician. Primary propellant ingredients are sulfur, charcoal and potassium nitrate.

DISPOSAL: Do not burn. Damaged, defective or unwanted rocket motors can be rendered useless by soaking in water for several minutes.

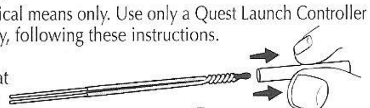
CAUTION: FOR YOUR SAFETY: DO NOT Alter, Disassemble or Tamper With Rocket Motor Ingredients In Any Way.

SELECTING THE CORRECT ROCKET MOTOR: Consult the current Quest Catalog, Website, product packaging or instruction sheet for recommended rocket motors to use in your model. Follow all igniter and rocket motor installation procedures.

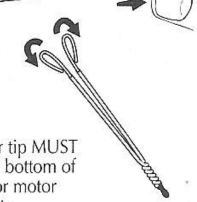
ELECTRIC IGNITER INSTALLATION

Launch your model rockets by electrical means only. Use only a Quest Launch Controller and igniters. Install igniters carefully, following these instructions.

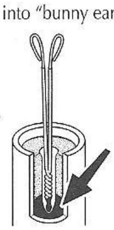
Step 1 Remove the plastic straw that protects igniter tip during shipping.



Step 2 Bend igniter leads into "bunny ears" as shown.

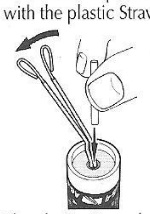


Step 3 Insert the igniter tip into rocket motor nozzle as far as it will go.



Black igniter tip MUST TOUCH the bottom of the nozzle or motor will not ignite.

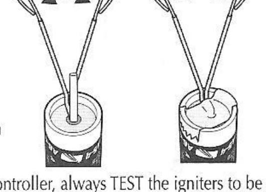
Step 4 Bend igniter over end of motor and secure in place with the plastic Straw.



-OR-

Step 4 Bend igniter over end of motor and secure in place with masking tape.

The plastic straw also acts as a stand-off to keep the rocket up and away from the blast deflector plate.



Step 5 Carefully pull the two leads away from each other to form a "V" shape.

WARNING! If using another brand of Launch controller, always TEST the igniters to be sure they are continuity safe. These igniters may be actuated when the safety key is inserted in other types of controllers.

LAUNCH SITE SELECTION: Select a large area away from trees, power lines, structures and low flying aircraft. Parks, playgrounds, soccer and football fields make great launch sites. DO NOT LAUNCH ROCKETS IN AREAS WITH BROWN GRASS, DRY WEEDS OR ANY HIGHLY FLAMMABLE MATERIALS. The larger the launch site the easier it will be to recover your rocket. See the N.A.R. Safety Code for additional information.

N.A.R. MODEL ROCKET SAFETY CODE

Approved February 10, 2001

NAR
NATIONAL ASSOCIATION OF ROCKETRY
www.nar.org

1. **MATERIALS.** I will use only lightweight, non-metal parts for the nose, body, and fins of my rocket.
2. **MOTORS.** I will use only certified, commercially-made model rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.
3. **IGNITION SYSTEM.** I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.
4. **MISFIRES.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
5. **LAUNCH SAFETY.** I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller, and 30 feet when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.
6. **LAUNCHER.** I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of the rod when it is not in use.
7. **SIZE.** My model rocket will not weigh more than 1500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 pound-seconds) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than 4 ounces (113 grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.
8. **FLIGHT SAFETY.** I will not launch my rocket at targets, into clouds, or near airplanes, and will not put any flammable or explosive payload in my rocket.
9. **LAUNCH SITE.** I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

LAUNCH SITE DIMENSIONS

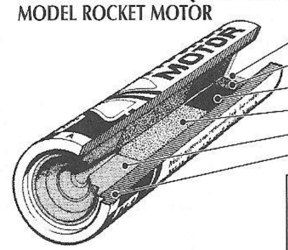
Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Site Dimensions (ft)
0.00 - 1.25	1/4A, 1/2A	50
1.26 - 2.50	A	100
2.51 - 5.00	B	200
5.01 - 10.00	C	400
10.01 - 20.00	D	500
20.01 - 40.00	E	1,000
40.01 - 80.00	F	1,000
80.01 - 160.00	G	1,000
160.01 - 320.00	Two G's	1,500

10. **RECOVERY SYSTEM.** I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
11. **RECOVERY SAFETY.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

COUNT DOWN PROCEDURE 1. When your rocket is ready to launch be sure you and all spectators are standing at least 15 feet away from the launch pad. **2.** Make sure the sky is clear of low flying aircraft. Wind conditions must be gentle. Be sure you have the attention of all individuals in the launching and recovery areas. **3.** Arm your Launch Controller with the Safety Key. The arming light should go on and the beeper should sound. If arming light does not go on, check battery power, electrical connections and igniter installation. Clean micro clips with sandpaper if necessary. **4.** With rocket armed announce to the spectators in a loud voice, "the rocket is armed and counting ...5...4...3...2...1...Lift-Off!" **5.** Push the launch button down until the rocket motor begins thrusting, then release it. The rocket should lift off from the pad almost instantly. **6.** BE SURE AND REMOVE THE SAFETY KEY FROM THE LAUNCH CONTROLLER AS SOON AS THE ROCKET LIFTS OFF. 7. REPLACE THE LAUNCH ROD SAFETY CAP IN BETWEEN LAUNCHINGS.

MISFIRE PROCEDURE
1. Occasionally, at the end of the countdown the rocket will fail to lift-off because the motor did not ignite. This usually occurs because the igniter was not making proper contact with the surface of the rocket motor's propellant.
2. Disarm the launch controller, wait one minute, then remove the rocket from the launch pad.
3.Remove the igniter from the motor nozzle, clean the micro clips and install a new igniter.
4. Repeat the countdown procedure again.

COMPONENTS OF A QUEST SINGLE OR UPPER STAGE MODEL ROCKET MOTOR



NOTE: A booster rocket motor does not have a delay charge, ejection charge or clay retainer cap.

ROCKET MOTOR PERFORMANCE: The thrust/time curve illustrates the thrust characteristics and performance capability of Quest Model Rocket Motors.

ROCKET MOTOR CLASSIFICATION CODING EXPLANATION:

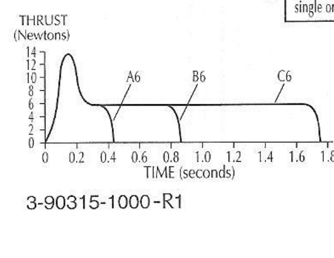
A — Letter is total impulse or total power produced by the motor. Each succeeding "letter" has double the power of the previous; for example, a "B" type motor is double the power of an "A" type motor.

6 — The first numeral indicates how fast the motor enables your rocket to travel. The higher the number, the greater the speed. The number itself stands for the average thrust in Newton-seconds, or the average force exerted.

4 — The last number is the delay code in seconds. This is the time duration from the end of thrust to the activation of the ejection charge.

A 6 - 4

NOTE: A "0" designation for the ejection charge indicates a booster motor, which will not activate a recovery system. DO NOT use booster motors for single or upper stage flights.



MOTOR TYPE	TOTAL IMPULSE	NEWTON 1-lb SEC	TIME DELAY	PROPELLANT WEIGHT
A6-4	2.5 N-sec	.56	4 sec	3.5 gram
B6-4	5 N-sec	1.12	4 sec	6.5 gram
C6-0	10 N-sec	2.25	NONE	12.5 gram
C6-3	10 N-sec	2.25	3 sec	12.5 gram
C6-5	10 N-sec	2.25	5 sec	12.5 gram

3-90315-1000-R1